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REMOTE MONITORING OF UPLIFT PRESSURES AT BARRETT CHUTE GS

Report No. 90-219-K

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ASTRACT

A remote monitoring system was installed at Barrett Chute GS to monitor uplift pressures in the bedrock foundation beneath the control dam. Data can be retrieved from the site at any time over telephone lines with the aid of a computer. This enables the engineer to be in constant touch with the project so that remedial actions can be undertaken at an early stage if and when necessary.

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REMOTE MONITORING OF UPLIFT PRESSURES AT BARRETT CHUTE GS

1.0 INTRODUCTION

A remote monitoring system has been installed by the Rock Sciences Section (Civil Research Department) at Barrett Chute Generating Station to measure uplift pressures within the bedrock foundation beneath the control dam. This report describes the installation of the instrumentation and communication network to access data from remote locations (ie, Civil Maintenance Department). Details relating to the geotechnical evaluation of foundation conditions are provided in a report prepared by the Civil Engineering and Architecture Department (Madawaska River: Barrett Chute GS - Main Dam: Geotechnical Evaluation of Foundation Conditions - 1989: Report No. 89518).

2.0 REMOTE MONITORING SYSTEM

The uplift pressure monitoring system (Figure 1) consists of the following major components: 1) vibrating wire piezometers with thermistors, 2) data logger and keyboard display, 3) multiplexer, 4) vibrating wire interface, 5) cassette player, 6) modems and telephone lines and 7) computers and peripherals.

2.1 Vibrating Wire Piezometers with Thermistors

The sensors used at Barrett Chute GS were Geokion model 4500 S vibrating wire piezometers. The instrument utilizes a sensitive stainless steel diaphragm to which a vibrating wire element is connected. In use, changing pressures on the diaphragm cause it to deflect, and this deflection is measured as a change in tension and frequency of vibration of the vibrating wire element. The square of the vibrating frequency is directly proportional to the pressure applied to the diaphragm. A coil and magnet assembly, located close to the wire, is used to pluck the wire and sense the resultant vibration frequency. A pulse of varying frequency is applied to the coil and magnet assembly, and this causes the wire to vibrate at its resonant frequency.

The wire continues to vibrate and a signal at the gauge frequency is induced in the pickup coil and transmitted to the data logger. The sensors used have a pressure range of 0–100 psi, an accuracy of ±.01% F.S., a resolution of 0.025% F.S., and an operating temperature of -29° to 65°C (-20° to 150°F). A filter stone is used with the gauge to prevent small particles from impinging directly on the diaphragm. The standard filter stone is made from sintered stainless steel with a 50 micron pore size. Saturation of this filter is not normally required since the air entry pressure is very low and the water will pass through the filter with practically no head required.

The vibrating wire probe includes a thermistor which is used to measure the temperature of the probe. Probe temperature is used to correct errors in the vibrating wire measurement caused by changes in the temperature of the probe. Unvented sensors were purchased for the following reasons: 1) cables containing the vent tube are more expensive; 2) vented sensors require the use of desiccant, which must be changed periodically, to dry the air entering the vent tube. An extra unvented sensor to measure barometric pressure for correction purposes was not purchased since the corresponding correction was considered to be negligible.

2.2 Data Logger and Keyboard Display

The Campbell Scientific CR10 is a fully programmable datalogger/controller packaged in a small rugged, sealed module. It is responsible for collecting, saving and transmitting data in response to the control program which is entered by the user. The user enters programs to the CR10 via a detachable keyboard/display or downloaded from a computer, which instruct the control module to initiate measurements or control functions, process data acquired from the I/O module and store data in final storage. The PS34 12 volt Charging Regulator provides a regulated and fuse protected 12 volt output for use with the CR10 provided it is connected to a 12 volt battery (gel cell). The PS34 accepts an input voltage in the range of 16 to 26 VDC from an AC to DC wall plug voltage converter.

2.3 Multiplexer

The primary function of the AM416 multiplexer is to increase the number of sensors that may be scanned by the CR10 datalogger. The CR10 datalogger is the only Campbell Scientific datalogger which has the capability of measuring vibrating wire pressure sensors, but is limited to only six differential input channels. This makes the CR10 an ideal candidate for multiplexing, since the project required the monitoring of seventeen pressure sensors and seventeen temperature sensors. The AM416 multiplexer is positioned between the sensors and the datalogger. Mechanical relays are used to switch the desired sensor signal(s) through the system. Four lines are switched simultaneously and a maximum of sixteen sets of (four) lines are scanned. This means that a total of 64 lines are multiplexed.

2.4 Vibrating Wire Interface

The AVW1 contains circuitry needed to interface the vibrating wire sensor to the CR10 datalogger. The AVW1 is designed to interface one vibrating wire sensor (temperature and pressure) to two single ended CR10 channels. It also provides important signal conditioning that 1) completes the thermistor bridge for the measurement of the sensor's temperature, 2) converts the swept frequency excitation from 2.5 volts peak to peak to 12 volts peak to peak, 3) provides transformer isolation and consequent noise reduction for the vibrating wire signal, and 4) provides additional transient protection for both the temperature and vibrating wire circuits.

One AVW1 interface was installed between the data logger and the multiplexer to provide signal conditional for sixteen vibrating wire sensors and sixteen thermistors. Another AVW1 interface was used to interface one vibrating wire sensor and thermistor directly to the data logger.

2.5 Cassette Player

A cassette recorder with a write only interface has been connected to the data logger on site. The collected data is not only saved in final memory storage on the data logger, but is also sent to the cassette recorder as backup.

2.6 Modems and Telephone Lines

Modems allow the data logger on site to communicate via telephone lines to a computer in a remote location. An originate Campbell Scientific DC112 modem at Barrett Chute GS converts asynchronous data from the RS-232 port of the data logger into synchronous data for transmission over the telephone lines. An answer modem (ie, Hayes Smartmodem 1200) at the remote location (ie, Civil Maintenance Department) converts the synchronous data into asynchronous data prior to sending information into the RS-232 port of the computer for storage. The data transmission rate is either 300 or 1200 bits per second. In the past, the use of Hayes Smartmodems as originate modems have caused problems. They have, therefore, all been replaced with Campbell Scientific DC112 modems.

2.7 Computer and Peripherals

An IBM compatible computer with a RS-232 port, 640K memory and preferably a hard disk is required to collect data and convert it into a user-friendly format. The computer should have a printer and/or plotter to print and plot data. In the past, programs such as Lotus 1-2-3 and Freelance Plus have been used to plot the data.

3.0 INSTALLATION

3.1 Vibrating Wire Piezometers

A total of seventeen vibrating wire piezometers with thermistors were installed in boreholes which were drilled into the rock foundation beneath the Barrett Chute GS control dam. The locations of the boreholes are shown in Figure 2 and summarized in Table 1.

The following provides a brief description of the installation process for each location (Figures 3 to 11). The depth of the hole was first measured to provide a datum from which to proceed. Pea gravel was repeatedly dropped into the borehole and tamped until it was filled to a depth which was three feet below the designated piezometer zone. A three foot thick bentonite seal was then established above the gravel zone by dropping bentonite pellets into the borehole. In the angled holes, a weight was lowered and raised after each interval of bentonite dropping to ensure that no bentonite would stick to the walls of the borehole. Once the bentonite plug was established, half of the piezometer zone was filled with filter sand. The sand was tamped to discourage future settlement. At this point, the vibrating wire piezometer was carefully lowered into the borehole until the sand level was contacted. The borehole was then filled with sand with periodic tamping until the top of the piezometer zone was attained. A three foot thick bentonite seal was then placed above the piezometer filter zone. The remainder of the hole was then filled with gravel. In boreholes where two piezometers were installed, the process was repeated for the second piezometer zone. The tops of the boreholes were filled with insulating foam. The foam in the boreholes located on the downstream toe were covered with tar to keep the sun's rays from breaking down the foam.

3.2 Transmission Cables and Conduits

The transmission cables which connect the piezometer and thermistors to the data collection centre

were all 4 wire (double twisted pair). For protective purposes, the transmission cables were placed inside of PVC conduits. Junction boxes permitted individual sensor cables to be connected into the main network. Protective caps were placed above the junction boxes located outside of the dam on the downstream toe. These caps provide protection against falling objects. The PVC conduit in the inspection chamber was fastened to the walls and roof while the conduit outside of the dam was mostly buried beneath gravel backfill.

3.3 Data Logger and Peripherals

The data logger, keyboard display, two vibrating wire interfaces, multiplexer, modem, voltage converter, charger, battery and tape cassette were installed inside of an environmental box, which was mounted on the wall in the south end of the inspection chamber. A 120 volt power line was run into the box to power the equipment. A telephone line was also wired into the box from the top of the dam. This telephone line enables communication with the data logger from remote locations.

The data logger was programmed to collect readings from all of the pressure sensors and thermistors every 15 minutes and store them in intermediate storage for further processing. At the end of a 24 hour period, beginning and ending at midnight, all readings taken at 15 minute intervals during the day are averaged to provide one daily reading. The daily readings are then sent to final storage, where they can be accessed for examination.

During the initial setup, readings taken by the CR10 data logger were cross-checked with a rental vibrating wire readout box (Model GK-401). The readout box is a lightweight, portable unit which provides excitation, signal conditioning and manual readout capabilities.

3.4 Data Reduction

Since the standard piezometer is hermetically sealed at the time of assembly, it responds to changes in the atmospheric pressure, particularly for the sensitive, low pressure models. The sensors used at Barrett Chute GS were all 100 psi models and were not considered to be sensitive enough to be affected by changes in barometric pressure. No corrections for barometric pressures were therefore required.

Because of the slight variability of materials used in construction, the sensors are affected slightly by changes in ambient temperature. Since piezometers are normally installed in a tranquil and constant temperature environment, corrections are not normally required. However, since all transducers are equipped with thermistors for temperature measurement, corrections are being carried out anyway. The following equation applies to corrections for temperature:

$$P_T = (R_0 - R_1)(-C) + K\,(t_1 - t_0)$$

where
P_T = pressure corrected for temperature
R_0 = initial reading at zero pressure
R_1 = reading at subsequent pressure
C = calibration factor (from factory calibration)
K = thermal factor (from factory calibration)
t_0 = initial temperature
t_1 = subsequent temperature

Pressure in "psi" units versus time is provided by the data logger. Examples of pressure change with time for a period of about six months are shown in Figures 12, 13 and 14. All seventeen piezometers

3.5 System Performance

At the time of writing, the uplift pressure monitoring system has been in operation for approximately six months (Figures 12 to 14). Although the system appears to be functioning well, a few rapid increases and decreases in pressure have been noted in the results (ie, BC-55 at 14.35 ft, BC-19 at 13.20 ft and BC-11 at 30.0 ft). These pressure changes are most likely due to the opening and closing of the pressure relief valves within the inspection chamber.

4.0 RECOMMENDATIONS

In order to maintain a highly functional and useful monitoring system, the following recommendations should be observed:

1) Data should be collected and viewed regularly.

2) Questionable performance or data should be reported as soon as possible to the Rock Sciences Section (Civil Research) so that equipment checks can be performed.

3) The monitoring system at Barrett Chute GS should be checked at least once a year to ensure that the equipment is properly maintained.

4) Any alterations required in the computer program, which collects and analyzes the data from the site (not plotting and printing programs such as Lotus 1-2-3), should only be undertaken after consultation with the Rock Sciences Section (Civil Research). This is necessary to enable efficient trouble-shooting if required.

5.0 CONCLUSIONS

The Rock Sciences Section (Civil Research) has installed a remote monitoring system at Barrett Chute GS to monitor uplift pressures within the bedrock foundation beneath the control dam. All data can be retrieved from the site and viewed on a remote computer (ie, Civil Maintenance Department) in a matter of minutes. This permits the engineer to be in touch with the site instrumentation so that remedial measures can be instigated at an early stage if and when required.

6.0 ACKNOWLEDGEMENTS

The authors wish to thank the staff at Barrett Chute GS for their excellent co-operation and assistance in carrying out this program. Mr. James Forest is acknowledged for his valuable contributions to this report.

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TABLE 1

BARRETT CHUTE GS - LOCATION OF INSTALLED PIEZOMETERS					
Borehole	**Chainage**	**Location**	**Bearing/Dip (Deg/Deg)**	**Piezometer Zone (Ft)**	**Piezometer Depth (Ft)**
BC-55	6 + 37	D/S Toe	S72W/60	11.0-21.0	14.35
BC-54	7 + 25	D/S Toe	S72W/60	28.5-33.5	30.30
BC-53	8 + 19	D/S Toe	S72W/40	15.5-20.5	19.00
BC-53A	8 + 19	D/S Toe	S72W/65	30.5-38.5	33.00
BC-52	8 + 82	D/S Toe	S72W/40	17.0-22.0	18.75
				37.0-42.0	38.50
BC-52A	8 + 82	D/S Toe	S74W/65	30.0-35.0	31.50
BC-11	3 + 6.4	Insp Cham	----/90	8.0-13.0	10.70
				24.0-34.0	30.00
BC-10	4 + 05.5	Insp Cham	----/90	15.0-20.0	17.60
				25.0-35.0	30.00
BC-4	4 + 89.5	Insp Cham	N72E/60	20.0-30.0	28.50
				38.0-43.0	40.00
BC-19	6 + 40	Insp Cham	S40W/65	10.0-15.0	13.20
				28.0-33.0	28.00
BC-28	7 + 20	Insp Cham	S18E/70	7.5-12.5	10.25
				46.0-56.0	49.80

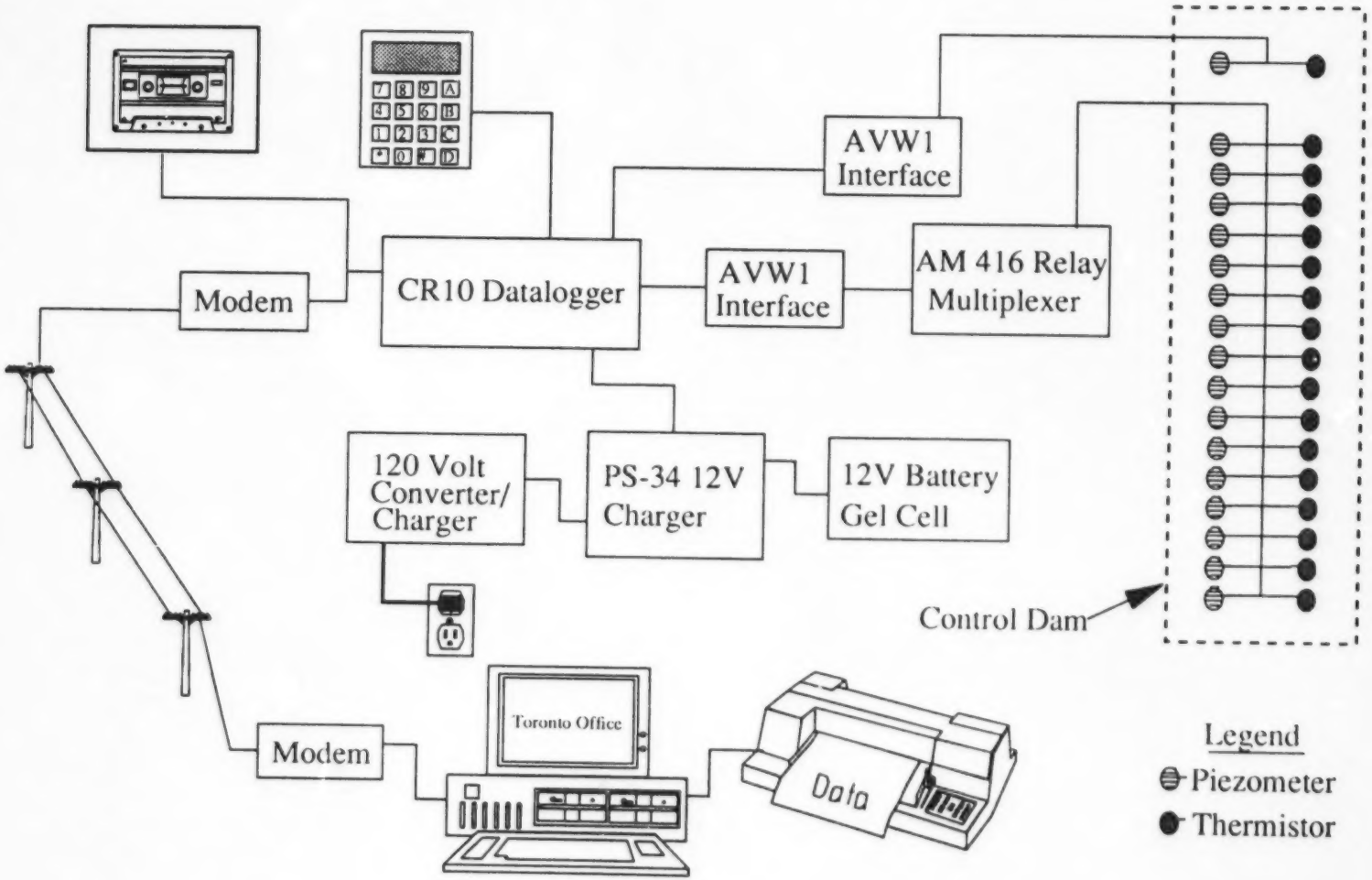
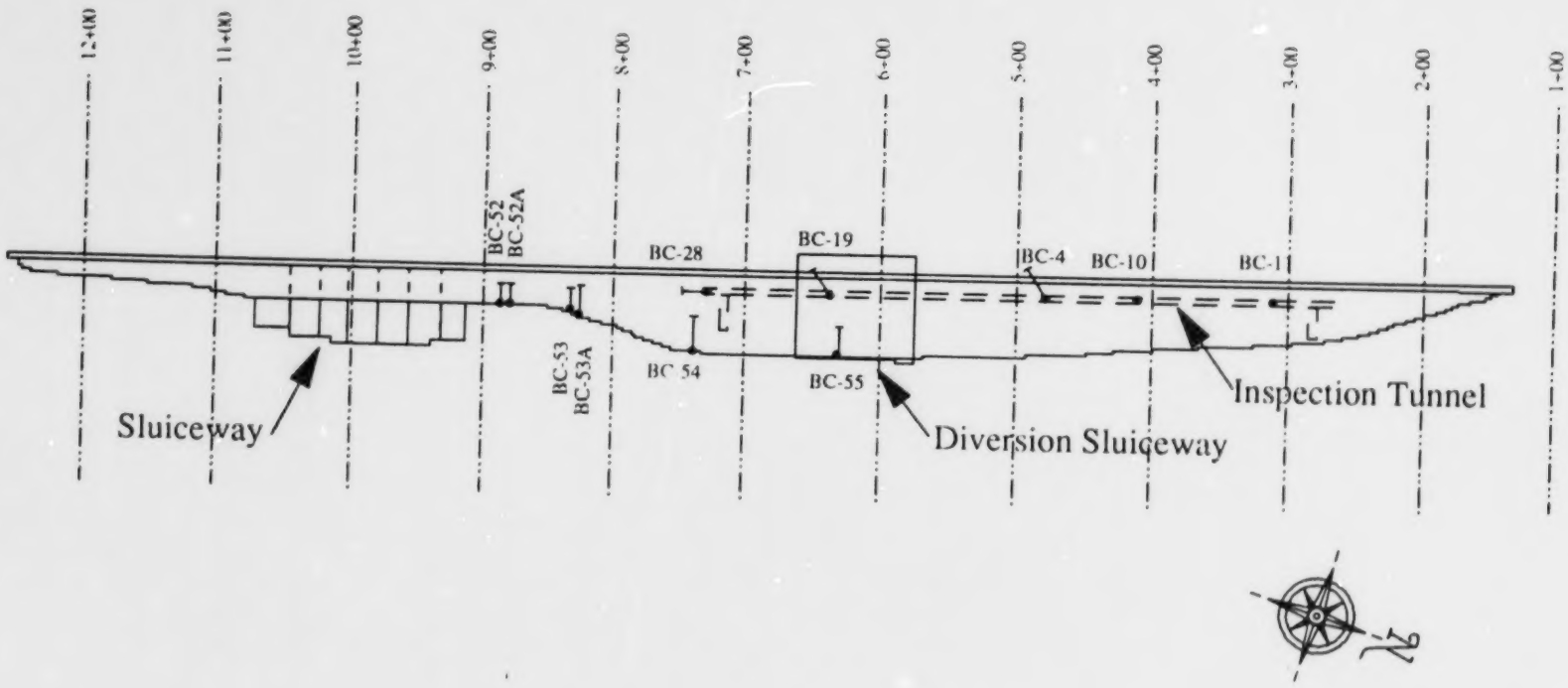
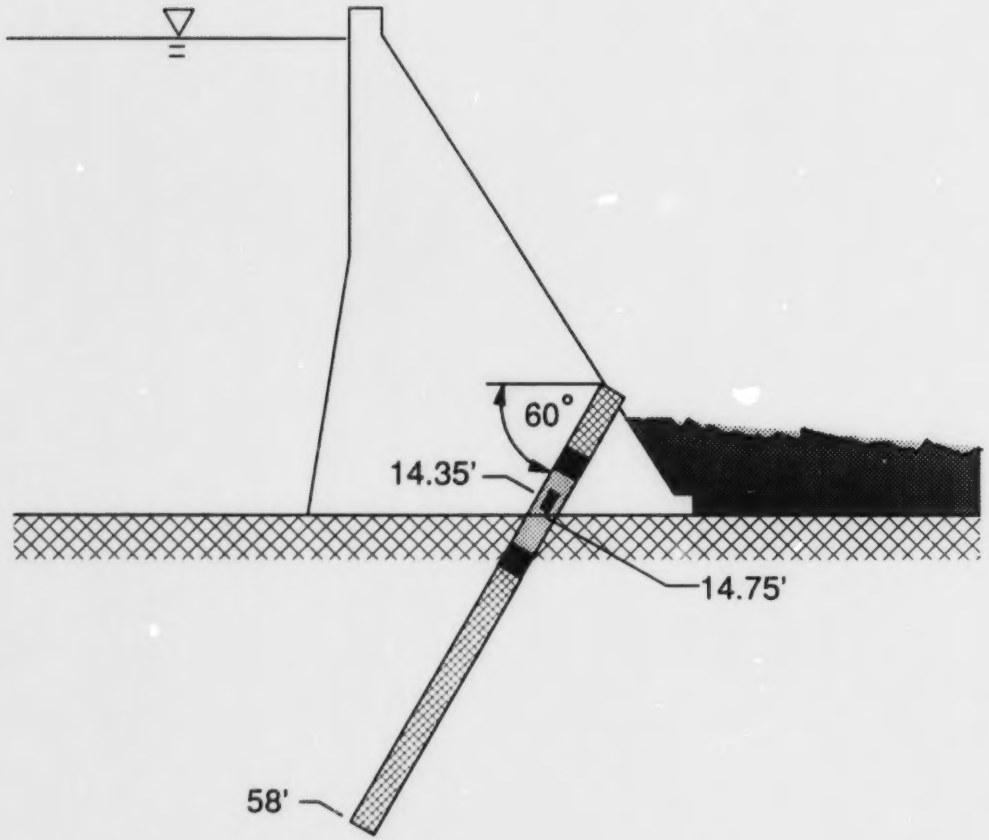


Figure 1
Barrett Chute GS Control Dam Monitoring



Scale: 1 inch = 130 feet

Figure 2
Plan View Showing Location Of Piezometer Holes



Legend:

- Piezometer
- Bedrock
- Gravel
- Bentonite
- Concrete
- Overburden
- Sand

Not To Scale

Figure 3

Cross-Sectional View of BC-55 At Chainage 6+37

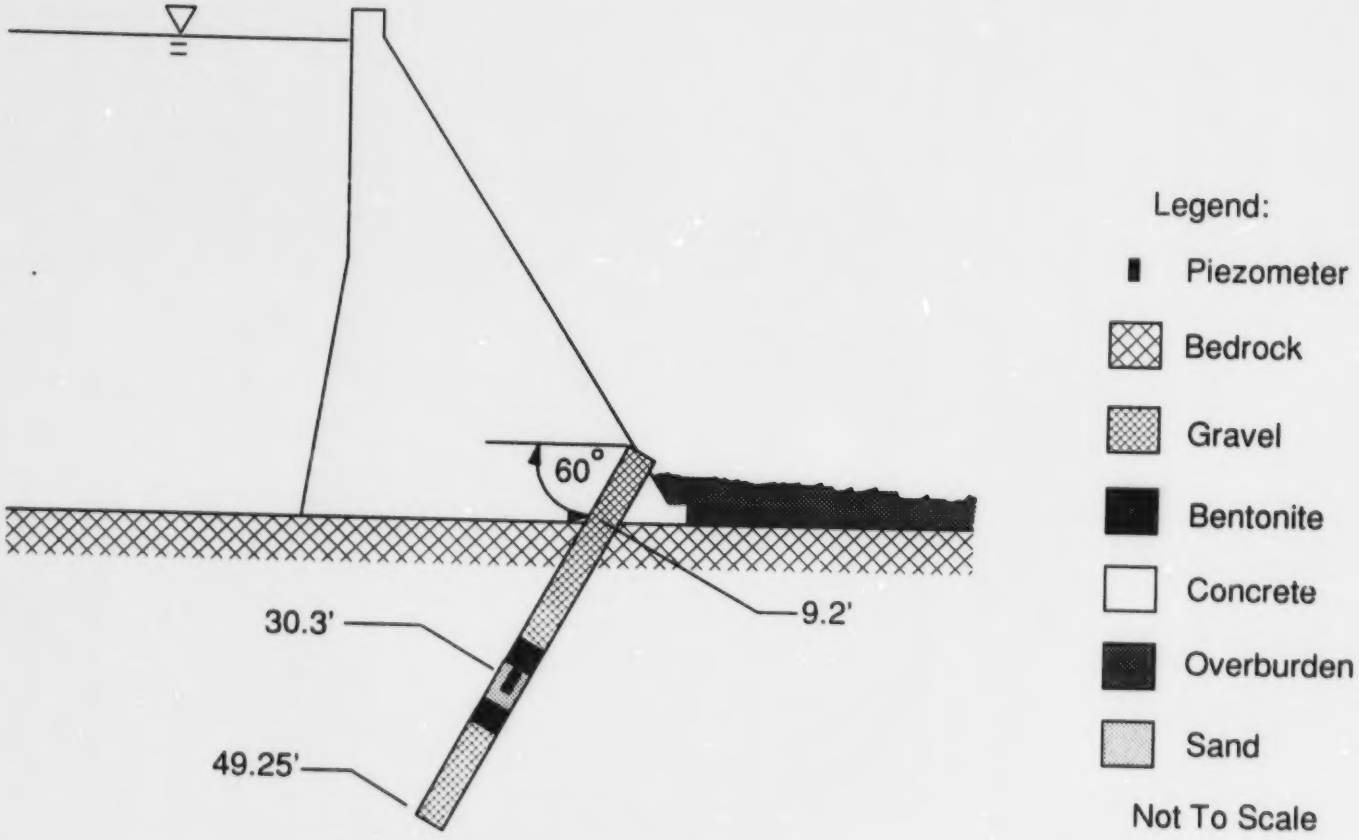


Figure 4

Cross-Sectional View Of BC-54 At Chainage 7+25

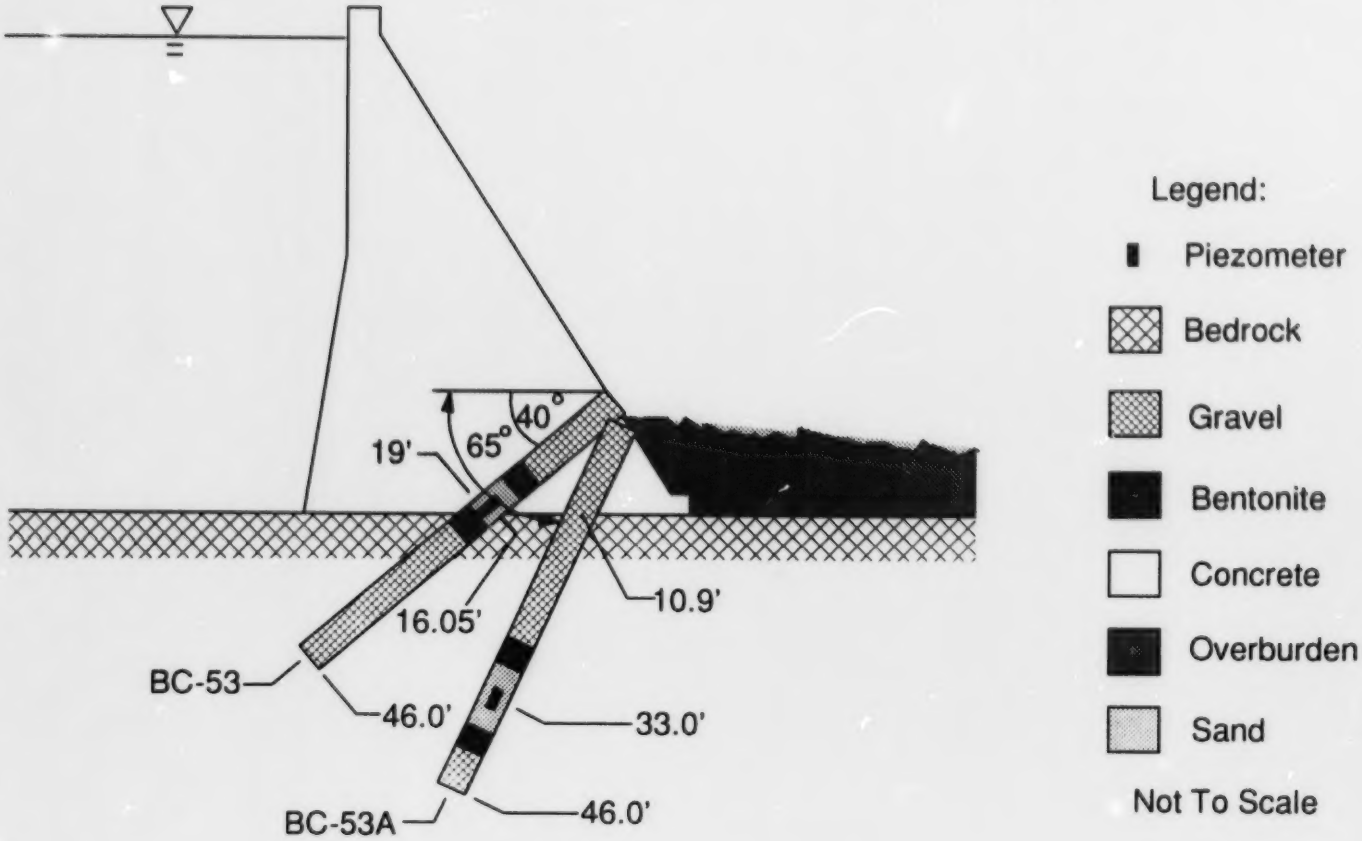


Figure 5

Cross-Sectional View Of BC-53 And BC-53A At Chainage 8+19

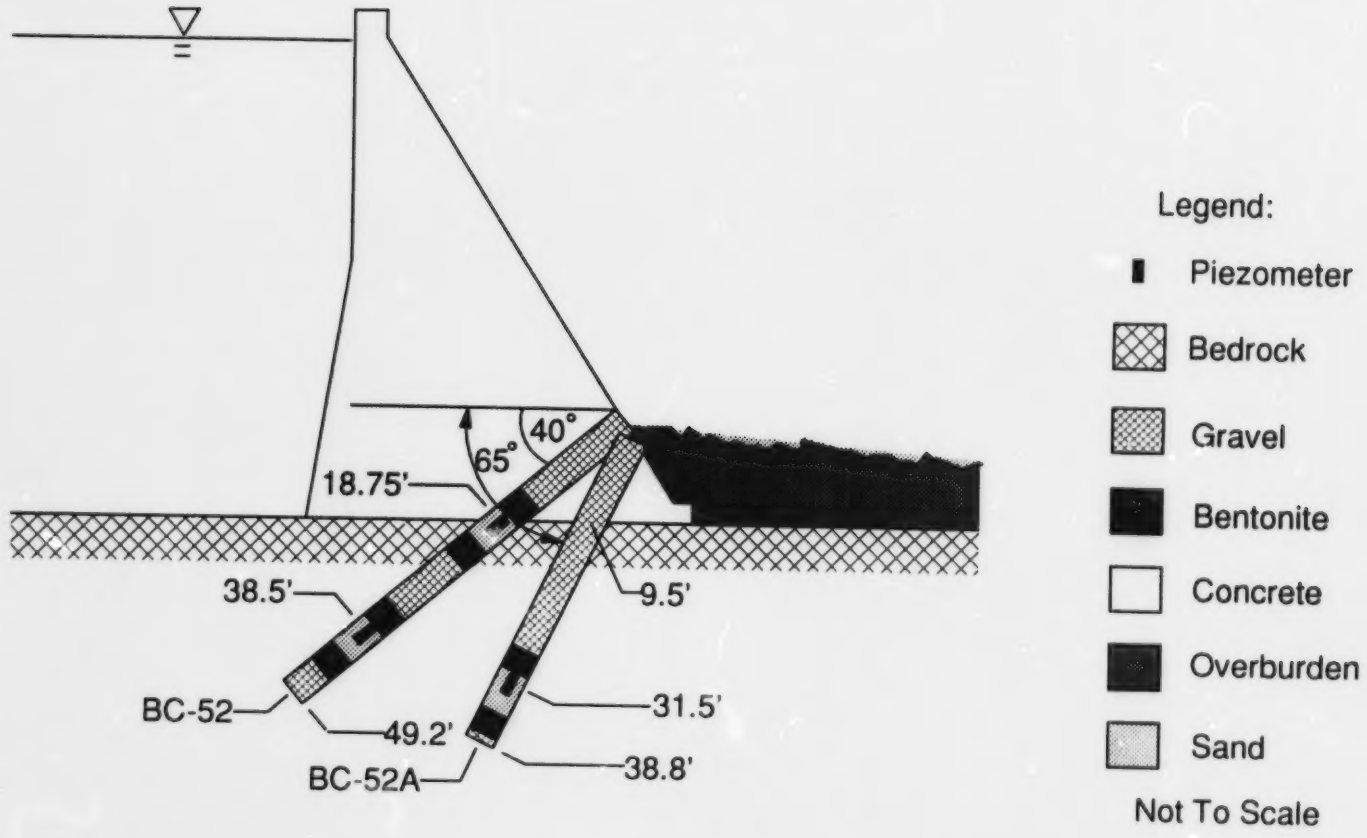


Figure 6

Cross-Sectional View Of BC-52 and BC-52A At Chainage 8+82

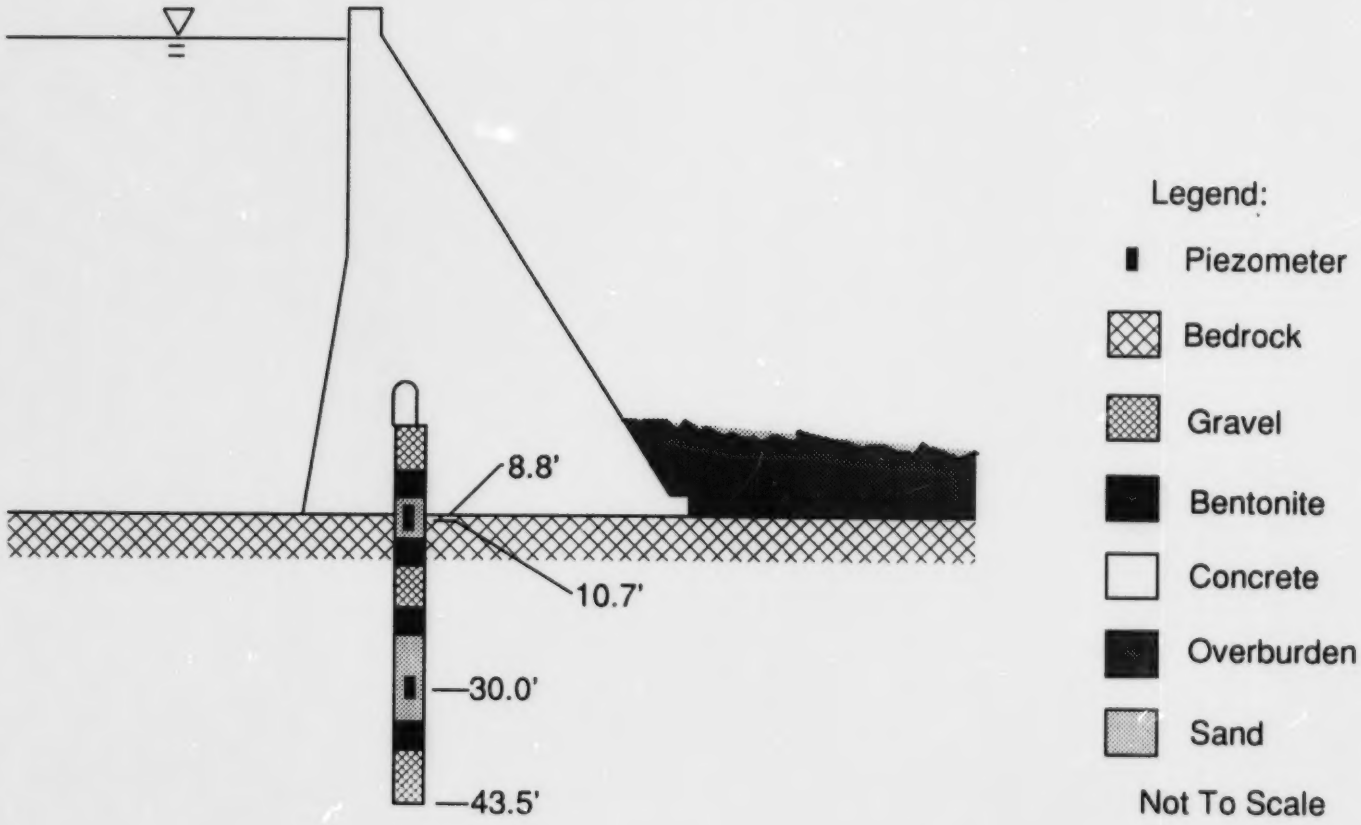


Figure 7

Cross-Sectional View Of BC-11 At Chainage 3+06.4

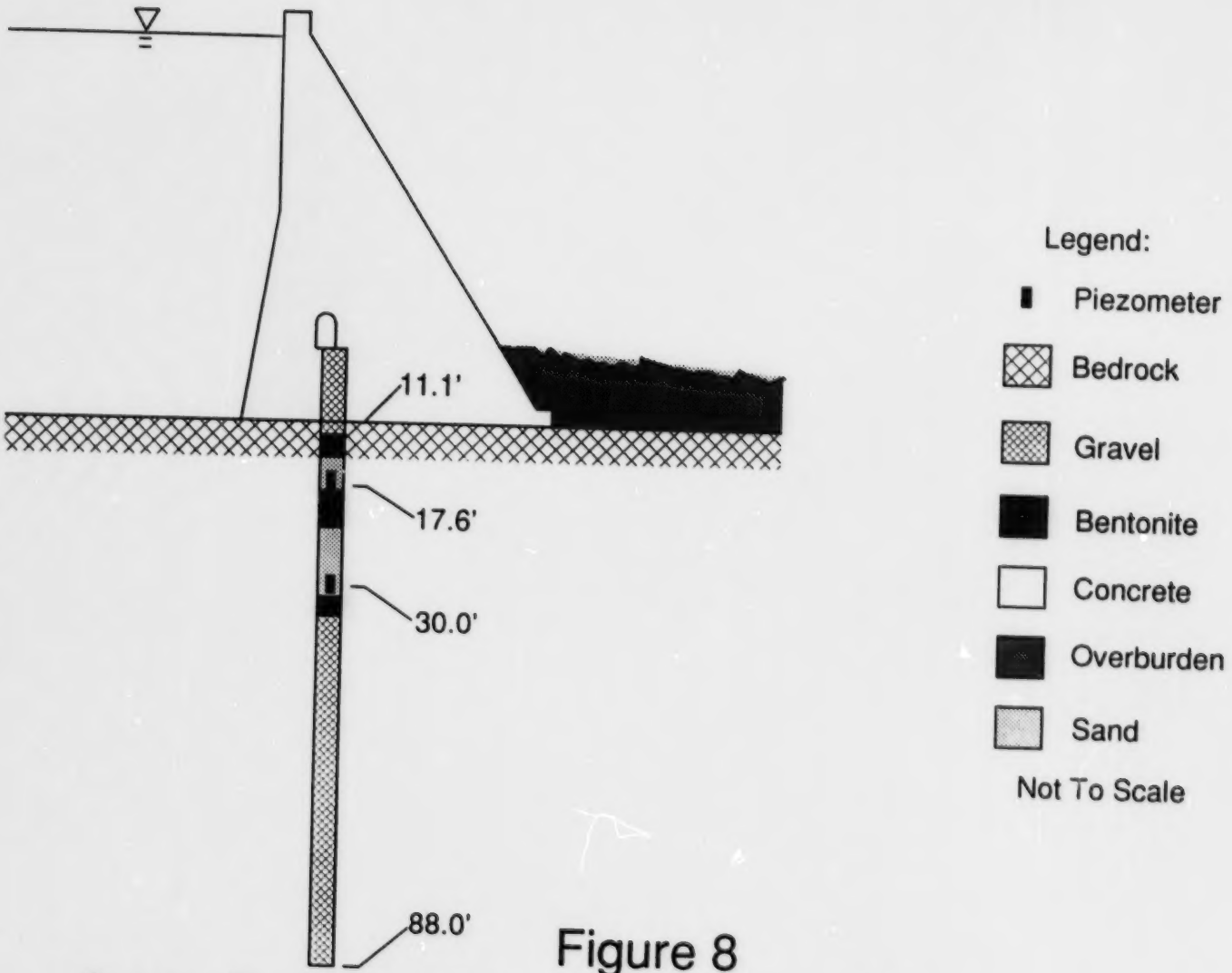


Figure 8
Cross-Sectional View Of BC-10 At Chainage 4+05.5

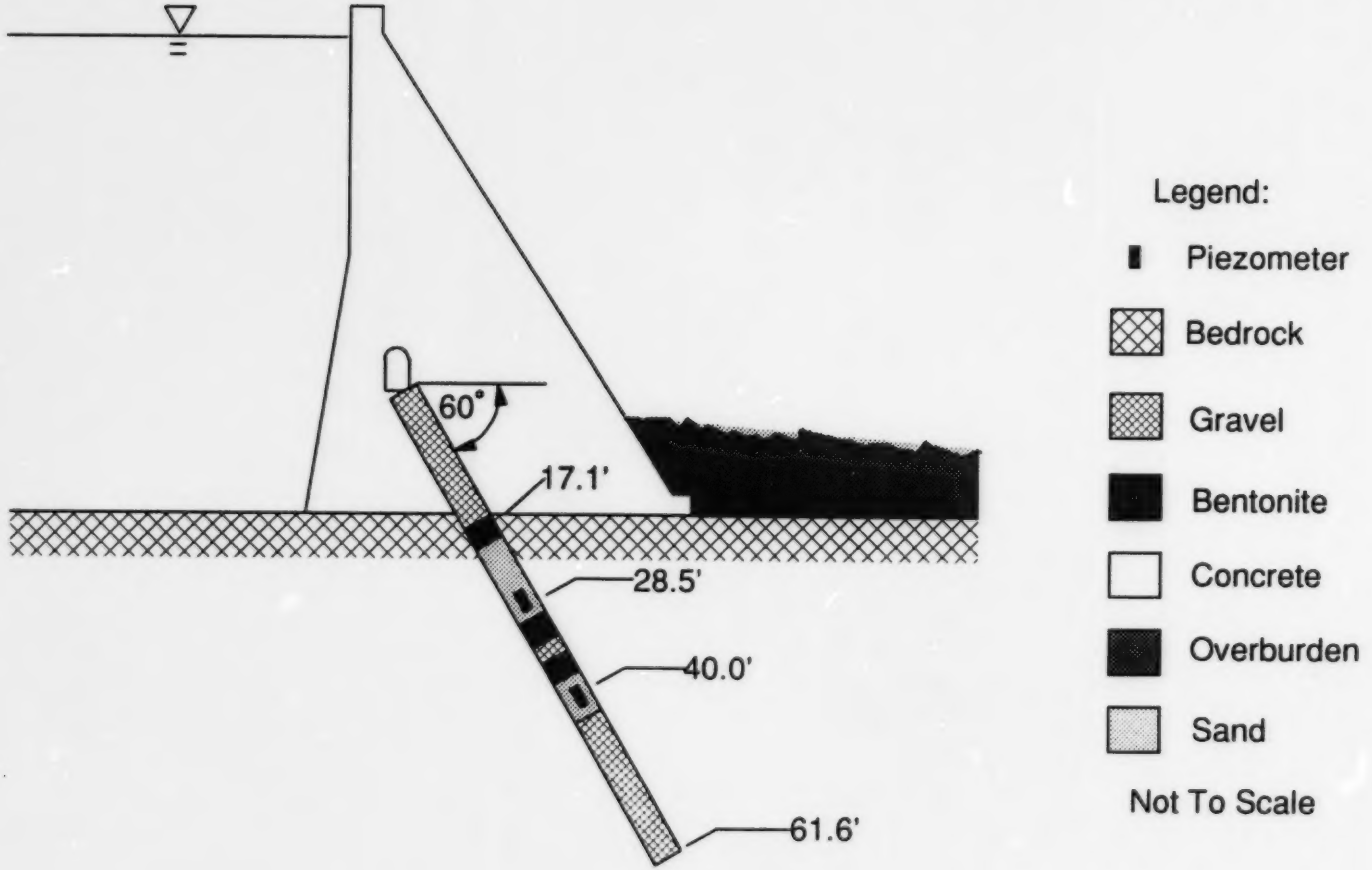


Figure 9

Cross-Sectional View Of BC-4 At Chainage 4+89.5

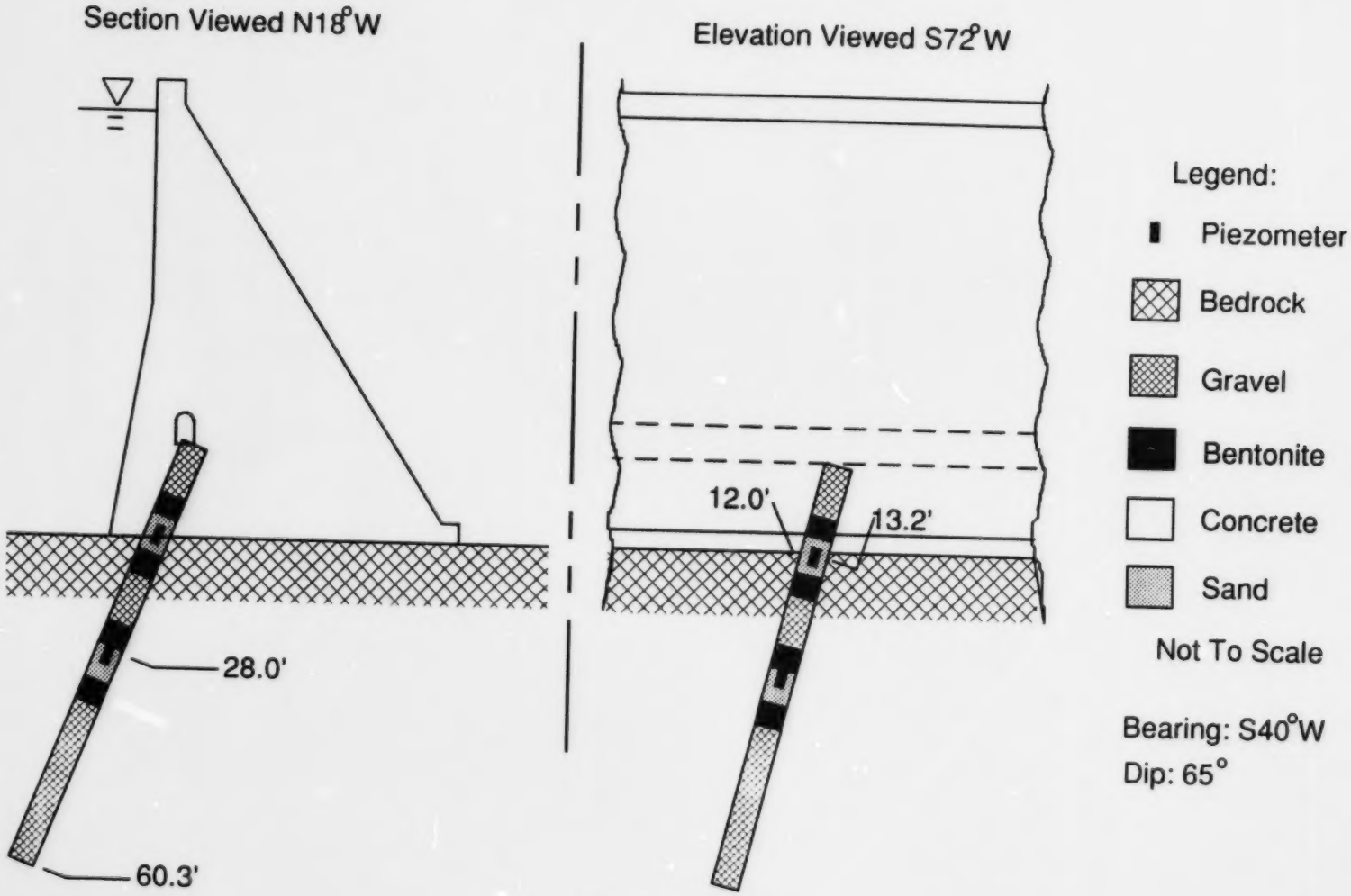


Figure 10

Cross-Sectional And Elevation View of BC-19 At Chainage 6+40

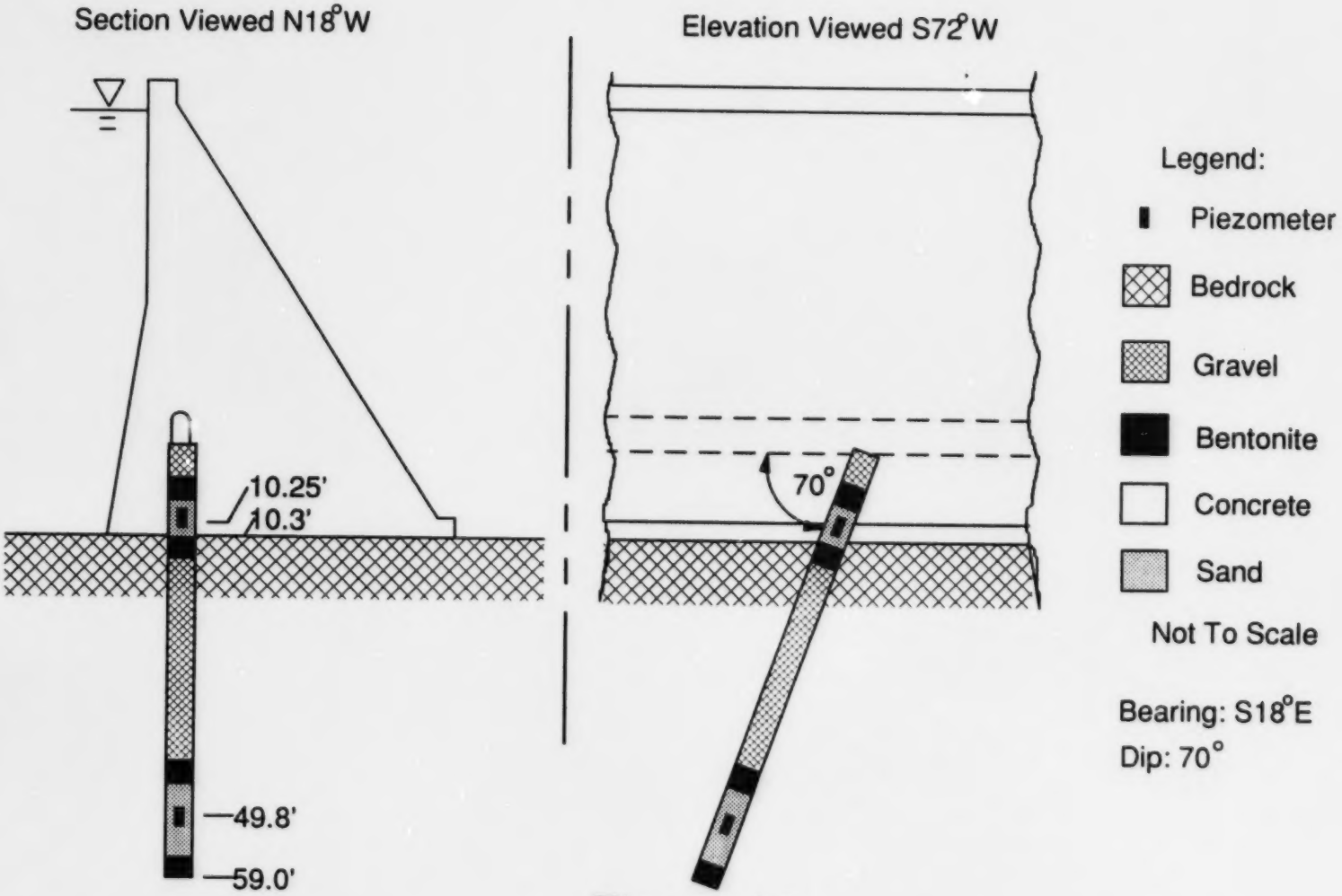


Figure 11

Cross-Sectional And Elevation View Of BC-28 At Chainage 7+20

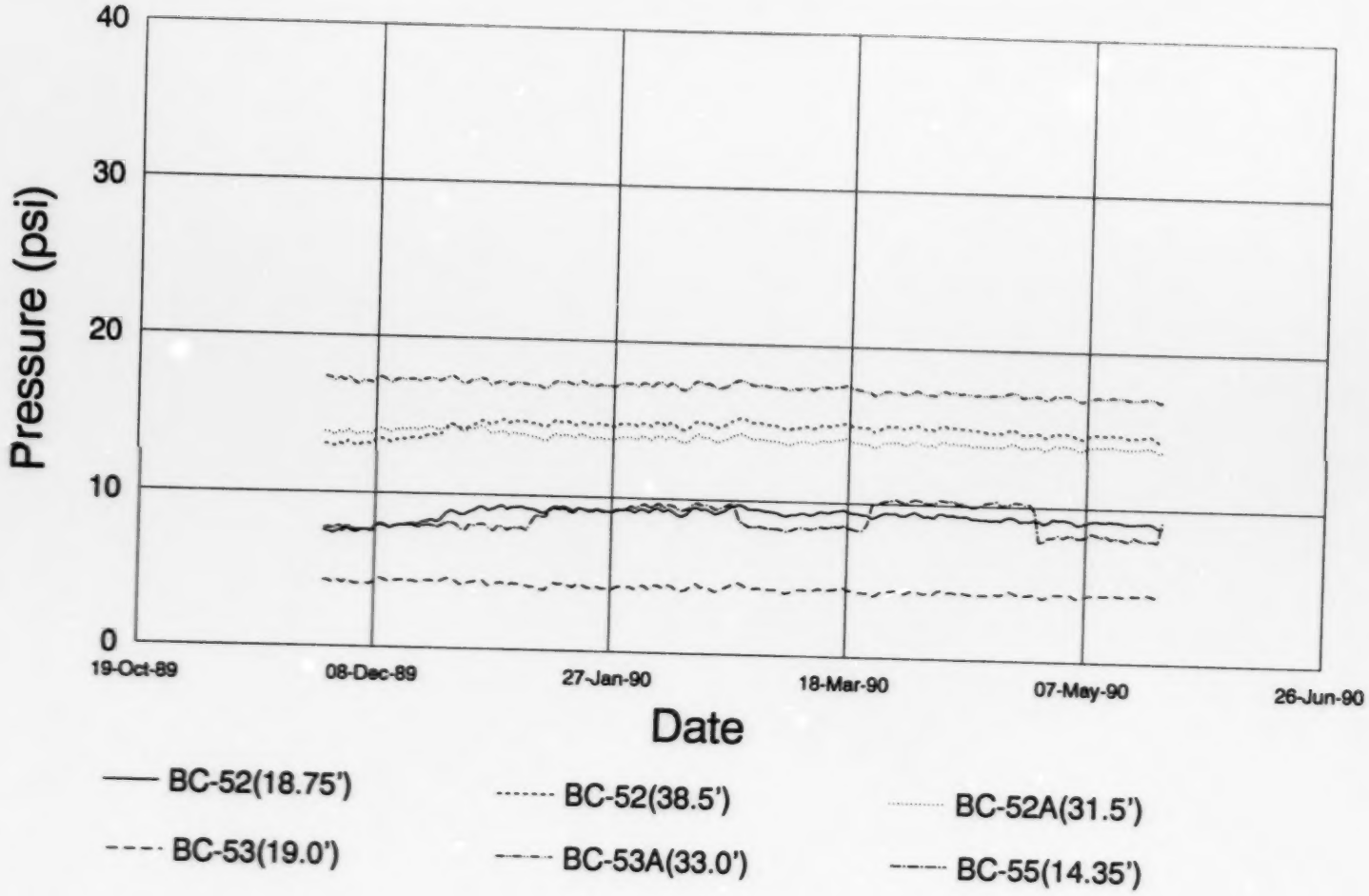


Figure 12

Barrett Chute GS Piezometers #1-6

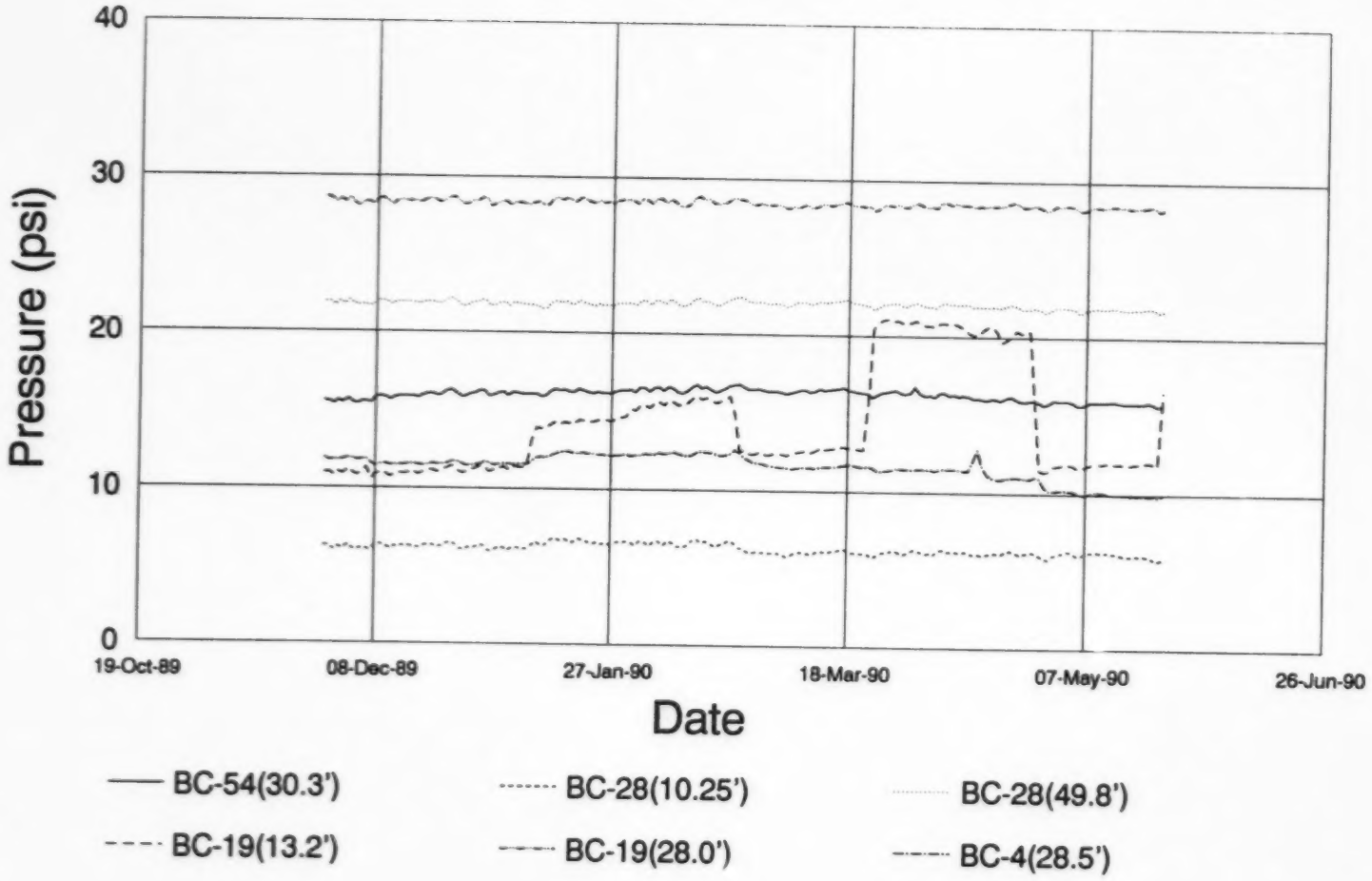


Figure 13

Barrett Chute GS Piezometers #7-12

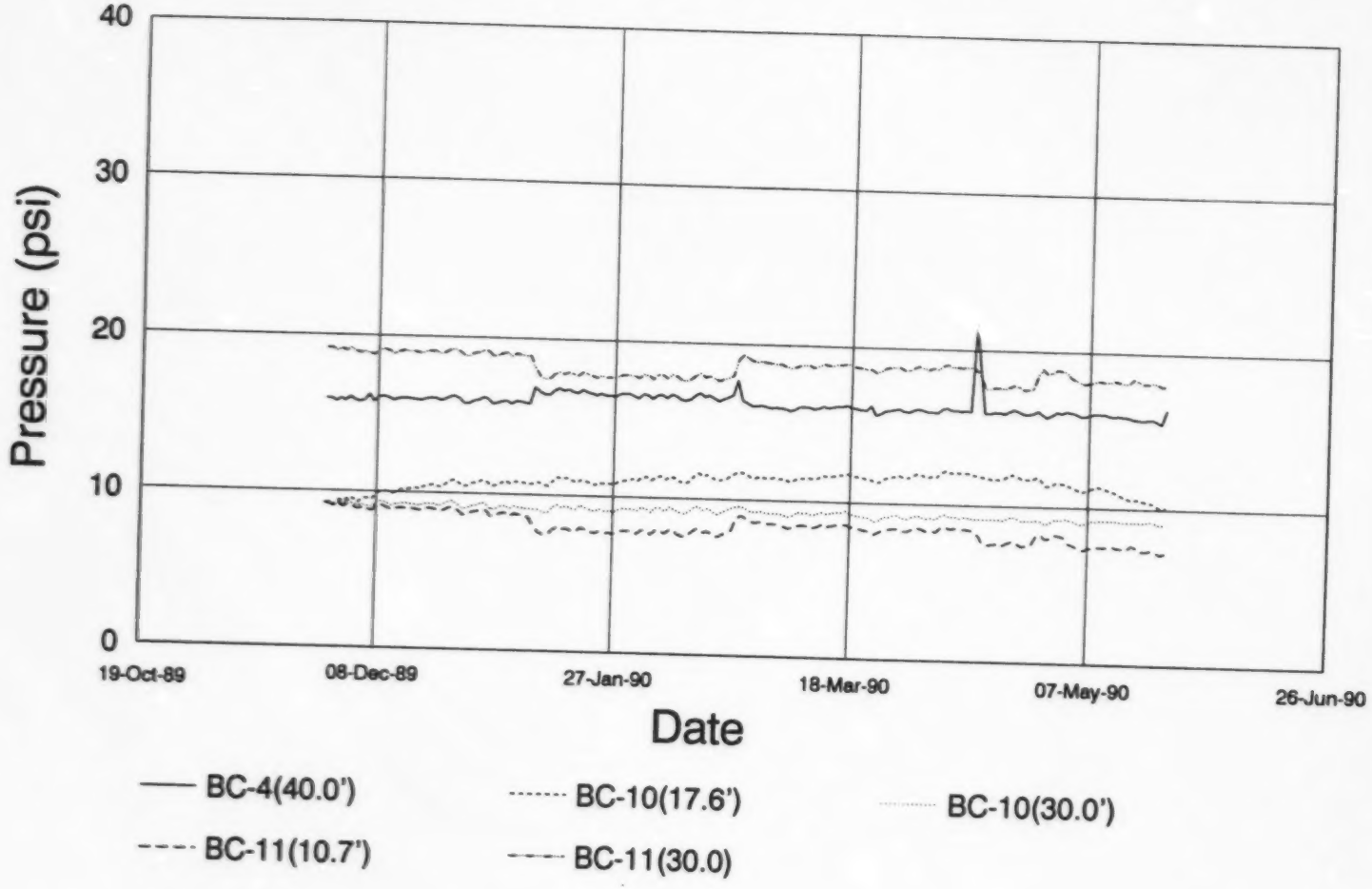


Figure 14

Barrett Chute GS Piezometers #13-17